A Summary of Current Program and
Preliminary Report of Progress

-

RESEARCH
on

NAVAL STORES and MAPLE SAP AND SIRUP PROCESSING AND PRODUCTS
and

REVEGETATION and WEED AND BRUSH CONTROL ON FOREST
AND RELATED RANGES

of the Agricultural Research Service,
United States Department of Agriculture
and cooperating
State Agricultural Experiment Stations

This progress report of U.S.D.A. and cooperative research is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of progress on U.S.D.A. and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having an interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued during the past year. Current agricultural research findings are also published in the monthly U.S.D.A. publication Agricultural Research.

UNITED STATES DEPARTMENT OF AGRICULTURE
Washington, D. C.
1965

TABLE OF CONTENTS

Copies of this report may be obtained from David J. Ward, Executive Secretary, Forestry Research Advisory Committee, U. S. Department of Agriculture, Washington, D. C. 20250

INTRODUCTION

This is ONE part of a TWO part report of cooperative U.S.D.A. research relating to all aspects of forested land and related ranges.

This part of the Forestry report deals with research conducted by certain divisions in the Agricultural Research Service; the other and larger part includes discussions of all Forest Service research. Limited information about work in cooperation with State Agricultural Experiment Stations is included in discussions of research progress.

Agricultural Research Service (ARS) investigations with naval stores and maple sap and sirup deal with the development of new and improved products and processing technology and the acquisition of basic knowledge about chemical composition and chemical and physical properties of these products. During the past fiscal year, about 21 professional man-years were devoted to these areas of utilization research.

The portion of ARS range improvement research covered in this report deals with problems associated with revegetation and fertilization of forest ranges. Methods of seeding, establishing, and managing ranges for domestic livestock are studied together with evaluations of the suitability of grass species or varieties for use as range plants. ARS investigations in this area involved about 3 professional man-years in fiscal year 1965.

Research on the control of weeds and brush on forest and related grazing lands is a part of ARS weed control studies with forage and range plants. In fiscal year 1965 about 27 professional man-years were devoted to the area of work covered in this report.

The above estimates of scientific effort do not include parts of some programs of a basic research that will produce results of value to many problem areas.

Successful applications of results of agricultural research have been numerous and impressive. A few examples from the research areas covered in this part of the report are presented here.

> New Peroxidic Product from Pine Gum Useful in Wide Variety of Applications. A new free-flowing, off-white solid peroxidic product with good industrial potential has been produced from crude pine gum by Department scientists. This low-cost material, called POPG, is made by chemically modifying the pine gum by a process known as photo-sensitized oxidation. Department research has shown that the pine gum peroxides are suitable for use in the polymerization of vinyl monomers, styrenated casting

resins, gum rosin, ester gum and other industrial products. The plastics industry is expected to find the new peroxides highly useful as curing or vulcanizing agents in most products such as vinyl plastics, and casting and laminating resins used in plastic boats and construction panels. Applications in the plastics and rubber industries appear particularly promising, since the new peroxidic product should be considerably less expensive than most peroxides conventially employed in these industries. The potential market for the new peroxidic products is estimated to be 12.4 million pounds valued at $6.2 million for 1964, and 17.4 million pounds valued at $8.7 million for 1969. Several companies are evaluating POPG and some of its derivatives in a variety of industrial applications. The mixed diepoxide derivative appears particularly promising, since diepoxy compounds are of considerable use in the plastics industry in the manufacture of adhesives and casting and laminating resins.

Maple Sirup. This year one large cooperative utilized its commercial fruit and vegetable processing equipment during the off season as a central evaporator plant to make maple sirup, with highly satisfactory results. The maple sirup produced was of high quality and was readily marketed. Because of the short crop this year, sap supplies were below expectations. Two additional food processors are now making plans to operate as a central maple sap processing plant during their off season.

Grazing Management. Range scientists at Fort Collins, Colorado, have developed a chart based on 20-years grazing data, to help ranchers of the Central Plains to obtain the best gains per animal or per acre from their range. If pounds of beef per acre is the objective, grazing should reduce forage to between 200 and 300 pounds per acre. If gain per head is the goal, about 400 pounds of forage should be left. The scientists hope to develop a simple method that will enable a rancher to estimate his forage closely and, especially, to know when he is reaching the danger zone (around 200 pounds per acre).

Enhanced Activity of a Herbicide. Absorption and translocation of an ester of 2,4,5-T in mesquite seedlings were significantly enhanced by the addition of 40% or more dimethyl sulfoxide (DMSO) to the aqueous carrier. The enhanced activity of 2,4,5-T induced by the higher DMSO concentrations was observed at light intensities ranging from 25 to 1,000 foot candles. Synergism also existed between DMSO and the herbicides, dicamba and picloram, but to a considerably lesser degree. At a concentration of 20%, DMSO was antagonistic toward the action of all

three herbicides. Anatomical and morphological responses to the 2,4,5-T - DMSO mixtures suggest that the latter compound increases uptake and general activity of 2,4,5-T, but that the two substances are probably not transported by the same mechanism or in the same tissues. Whereas 2,4,5-T translocates primarily to the meristematic regions such as the apical bud, the DMSO moves widely throughout the plant and concentrates in the leaf tips.

I. NAVAL STORES PROCESSING AND PRODUCTS
Southern Utilization Research and Development Division

Problem. More uses for pine gum, rosin and turpentine need to be developed through research to provide industrial markets for current and anticipated production of gum naval stores. Recent decreases in uses of gum rosin, especially in paper size, have resulted in the accumulation of a considerable surplus of this commodity. Other types of rosin as well as synthetic chemicals backed by strong industrial research programs have made serious inroads on the traditional markets for gum rosin. Gum turpentine is also faced with similar competition. If the turpentine farmers of the southeast are to continue to find profitable markets for their pine gum, existing knowledge of the properties of this commodity and its derived products must be used to develop new uses and strengthen old ones. New fundamental information about the chemistry of the terpenes and resin acids is also needed to fully exploit their unique characteristics. New or expanded uses for naval stores products are especially needed in polymers, plastics, elastomers, resins, plasticizers, surface coatings, textile finishes, odorants, insecticides, herbicides, and other large-volume industrial chemicals. There is also a serious need to improve existing processes and develop new processing technology for the industry.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program at Olustee, Florida, involving organic chemists and chemical engineer engaged in both basic and applied research to discover and develop new and improved uses for pine gum and its products. In research to develop new and improved industrial products from pine gum, rosin, turpentine, or their components, conversion of the resin acids derived from gum rosin and pine gum to new polyfunctional products by reaction with suitable chemicals is under investigation to develop intermediates for production of resins, plastics and related products. Another research approach involves the condensation of the unsaturated (olefinic) materials present in pine gum with certain reactive chemicals (dienophiles) to produce industrially useful chemicals. Research is being conducted to develop improved polyester resins from resin acids of pine gum and rosin; to study the preparation and reactions of epoxides and ozonization products of resin acids and their derivatives to produce materials having potential for use in plastics and other industrial products; to develop practical methods for converting levopimaric acid, resin acid mixtures, and/or pine gum to polyfunctional compounds useful in plastics, resins, and other industrial products by formaldehyde addition and subsequent reactions; to convert terpene acids, terpene acid derivatives, and rosin derivatives into polymerizable monomers suitable for making new polymere, plastics, and resins; and to produce reactive chemical intermediates from turpentine and terpenes derived from it by reaction with inexpensive dienophiles. The Pulp Chemicals Association has been supporting a Fellowship at the Naval Stores Laboratory for the purpose of conducting

research to develop a suitable method for determining rosin and rosin derivatives in protective coatings, a necessity if rosin is to be allowed in certain types of these coatings from which it is now excluded. This research has been successfully completed. Informal cooperation is maintained with other agencies and industrial firms in connection with the naval stores research program. The U. S. Forest Service cooperates by supplying selected samples of pine gum.

Additional research on new and improved industrial products is in progress under contract at the University of Cincinnati, Cincinnati, Ohio, on the application of the oxo and related reactions to terpenes and resin acids to produce new, useful alcohols, aldehydes, and/or acids, and the characterization of the products thus obtained; at Cornell University, Ithaca, New York, on the synthesis of terpene alcohols and glycols for use in the production of new and useful terpene derived polymers; and at the University of Florida, Gainesville, Florida, on the development of a practical process for the conversion of α-pinene to dimers in good yields, and the conversion of these dimers to useful, reactive derivatives.

Research in the field of chemical composition and physical properties is in progress under a grant of P.L. 480 funds to the Juan de la Cierva School of Technical Investigations, Barcelona, Spain, for development of new or improved methods of preparing selected terpene alcohols for use as standards, to obtain basic information on the composition and properties of products made from pine gum (project duration - 3 yrs.).

The Federal in-house scientific research effort in this area totals 15.0 professional man-years. All of this effort is on new and improved industrial products. The contract research involves an additional 2.7 man-years on new and improved industrial products. P.L. 480 research involves 1 grant for research in the field of chemical composition and physical properties.

The following lines of work under new and improved industrial products were terminated during the year: (1) Preparation of chemical intermediates from pine gum products for use in the preparation of new synthetic polymers, plastics and resins to expand the utilization of turpentine and rosin; (2) Hypochlorite modification of rosin and resin acids for use as chemical intermediate for preparation of new industrial resins, surface coatings, plastics, rosin soap emulsifiers and similar materials; (3) The utilization of photosensitized oxidized pine gum and components in the fields of plastics and rubber.

PROGRAM OF STATE EXPERIMENT STATIONS

State stations did not report work in this area.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Composition and Physical Properties of Pine Gum. Contract research at Purdue Research Foundation is developing fundamental information on the chemical transformations of terpene olefinic compounds by hydroboration and subsequent reactions. A systematic examination of the stereochemistry of the hydroboration reaction products of Δ 3-carene has been undertaken. In research thus far on the hydroboration of d-limonene, it has been found that selective external hydroboration can be achieved by reacting this terpene with disiamylborane (di-s-isoamylborane) at room temperature. In situ protonolysis studies have shown that the resulting organoborane can be quantitatively converted to l-p-menthene (carvomenthene) by reacting with dry isobutyric acid. The research findings should ultimately provide the basis for the synthesis of potentially useful products from terpenes. (S4 1-112(C)).

B. New and Improved Industrial Products

1. Development of Intermediates for the Production of Resins, Plastics, Plasticizers, and Other Industrial Products from Pine Gum and its Components. A study of the chemistry of the epoxides of esters of ∝-campholenol has been completed. The epoxides react in a manner such that their use in epoxy resins appears very unlikely. Their reaction with organic acids produces a mixture of compounds. The major component is a diol formed as a result of molecular rearrangement, and the other compound produced is a keto alcohol, which could be considered the normal reaction product. The diacetate of the mixture has attracted interest of perfume chemists. Copper chromite reduction of diethyl sym-homopinate gave almost quantitative yield of a cis and trans mixture of sym-homopinane diol (2,2-dimethyl-1,3-(2-hydroxyethyl)cyclobutane). This symmetrical glycol has unusual thermal stability and should be very useful industrially. (S5 2-38).

Research is being conducted to prepare polymerizable monomers for vinyl and condensation-type polymers from terpene and resin acid derivatives. Linear alkanoic and alkenoic esters of ∝-campholenyl epoxides were found to be acceptable primary plasticizers for polyvinyl chloride, imparting excellent long-term thermal stability to the plastic compositions. Since cheap fatty acids can be used to prepare these esters they should have industrial potential. ∝-Campholene aldehyde and diethyl pinate have potential as perfumes and are being evaluated by industry. Procedures have also been developed for preparing interesting glycols from pinonic, pinolic and homopinic acids, and presumably from pinonaldehyde. It is planned to place more research emphasis on rosin rather than terpene acids. The preparation of vinyl ethers of abietol and β-hydroxyethyl abietol and the vinyl ester of 6-hydroxymethyltetrahydroabietic acid will be studied. Research on the

synthesis of a number of polyethylene glycol esters and ethers of rosin-derived di- and tri-carboxylic acids and alcohols will also be initiated. (S5 2-55).

In further studies of the reaction of terpenes with dienophiles to produce useful chemical intermediates, three compounds were isolated from the reaction of fumaric acid with α-terpinene. Two of these were characterized as normal 1:1 adducts; the other is an unexpected, abnormal adduct. The production of the latter compound may be of considerable theoretical importance and may also affect the utility of the products. Cimethyl fumarate adds to α-terpinene to give the three corresponding methyl esters. Exploratory experiments have shown that dimethylmaleate adds readily to α-terpinene, gamma-terpinene, terpinolene and β-pinene, but not to α-pinene, dipentene or 2,4(8) p-menthadiene, to give 1:1 adducts. Even at 300° in the absence of acid the various terpenes do not isomerize and give the same adduct, and they differ widely in the ease with which they form adducts. These various reactions will be studied further. (S5 2-48).

In research to develop practical methods for preparing the levopimaric acid-formaldehyde adduct and selected derived products for industrial uses, yields of 80% of crystalline adduct have been obtained from 90% pure levopimaric acid using a solvent system which is applicable to large scale runs. The reaction can be run to give complete reaction of the levopimaric acid but in this case part of the adduct is converted to 6-methylolabietic acid. Also, 50% yields of crystalline adduct have been obtained directly from pine gum by procedures which can be scaled up without difficulty. Hydrogenation of the double bonds of the 6-methylolabietic acid gives a saturated hydroxy acid which is not susceptible to air oxidation. Reductive procedures are being investigated for converting the adduct to the potentially useful glycol product. (S5 2-51).

The research on hypochlorite modification of rosin and resin acids to produce chemical intermediates for industrial products has been discontinued. It was found that both abietic and levopimaric acids react readily with sodium hypohalite to introduce hydroxyl groups into the resin acid molecule. By this reaction, 6-hydroxyabietic acid was produced in 50% conversion from pure levopimaric acid with isolation of 30% of the purified material. Such a hydroxylated resin acid, or hydroxylated rosin, should be of value as a low cost extender for polyester and polyurethane resins. (S5 2-44).

Contract research has been initiated at the University of Florida on the development of a practical process for the conversion of α-pinene to dimers in good yields, and the conversion of these dimers to useful, reactive derivatives. All three catalysts investigated thus far for the dimerization reaction (boron trifluoride, phosphoric acid and sulfuric acid) produced complex products which contained isomerized terpenes, trimers, and polymers along with the desired dimers. The relatively good yields of mixed dimers

(in excess of 60%) obtained at this early stage of the work is encouraging. Efforts will be made to improve the techniques for separating and identifying the products and to find conditions which give less complex mixtures. (S5 2-49(C)).

2. Addition of Chemicals to Rosin Acids with Emphasis on Photochemical Methods to Produce Chemicals Useful in Manufacturing Surface Active Agents, Textiles, Paper and Plastics. In further research on photosensitized-oxidized pine gum (POPG), this material was converted to a mixture of diepoxides, from which the lead, barium and other metal salts were prepared. The lead and barium salts proved to be effective as stabilizers for poly-(vinyl chloride). The barium salt of POPG itself was an effective stabilizer and also exhibited antimicrobial activity. Industry has expressed interest in these products; they should provide a new, potential large-scale use for POPG other than as a low-cost source of free radicals. Another product prepared in the research--the hydroperoxide of methyl dihydroabietate--also has aroused the interest of industry. Some exploratory work on the strong-base isomerization of some major resin acids of gum rosin was carried out. Potassium tertiary-butoxide in dimethyl sulfoxide isomerized levopimaric acid to abietic acid. This is the first base-catalyzed isomerization of a resin acid that has been accomplished. In other work, gum rosin was maleated and varying portions of the anhydride carboxyls were neutratized with base. Under conditions simulating tank car storage, the samples treated with base did not crystallize as did the blank. On preparation of paper size from these materials, the same good results were obtained. A non-crystallizing fortified paper size should be of immediate interest to certain paper size manufacturers. This project has been discontinued and promising research leads on the preparation and reaction of diepoxides from photosensitized-oxidized rosin and resin acids are being investigated under a new project. (S5 2-47).

3. Conversion of Rosin Acids, Pine Gum and Turpentine into New Polymers, Protective Coatings, Resins and Plastics. Research has been initiated on the preparation and reactions of epoxides and ozonization products of resin acids and their derivatives to produce materials having potential for use in plastics and other industrial products. An improved process for preparing mixed diepoxides from photosensitized-oxidized pine gum (POPG) was developed. There is considerable industrial interest in POPG and the mixed diepoxide product. Crystalline products--12-α-hydroxyabietic acid and presumed 8α, 12α-dihydroxy-Δ^{13}-abietic acid--were isolated in good yield from the reaction of levopimaric acid with peracid. It should be possible to obtain polyhydroxy compounds of potential use in manufacturing polyurethane foams from resin acids in this manner. In exploratory work on the strong-base isomerization of some major resin acids of gum rosin, the isomerization of levopimaric, palustric, and abietic acids was accomplished with potassium tert.-butoxide in dimethyl sulfoxide to give an equilibrium mixture of about 70% abietic acid, 5% neoabietic acid, 5% palustric and/or

levopimaric acid, 5% of a new resin acid, 5% of a second new resin acid, and 10% of dehydroabietic acid in all cases. The preparation of polyamide-polyimide plastics, a new class of heat-resistant plastics, from maleopimaric acid and diamines was attempted but the desired high polymers have not yet been obtained. The chemistry of resin acid epoxides will be explored in an effort to find industrially useful derivatives. (S5 2-52).

Research has been initiated to develop improved polyester resins from resin acids of pine gum and rosin. Polyesters prepared from glycol and glycerol esters of heat polymerized rosin by further reaction with fumaric acid and diethylene glycol show promise. Cured ester-styrene copolymers of these polyesters equivalent to the better commercial products were obtained. Studies of methods for converting rosin acids into dibasic acids have shown that moderate yields of dibasic acids can be obtained by reaction of rosin with permaleic acid. The dihydro acids present in disproportionated rosin also react in a similar manner. The dibasic acids obtained in this way should be useful in a variety of products such as polyesters, polyamides and paper size. A practical method was discovered for isolating dehydro-abietic acid from commercial disproportionated rosin in good yields and excellent purity. It involves recrystallization of the ethanol amine salt of the disproportionated rosin from aqueous alcohol. This should encourage the commercialization of some of the derivatives of this acid. Also, the practical, less expensive method developed for preparing metal resinates directly from pine gum or from a mineral spirit solution of rosin should lead to increased utilization of these resinates. (S5 2-53).

The experimental work on polymerization of pine gum derivatives carried out under contract at the University of Arizona has been completed. Recent work has involved studies of the polymerization of vinyl butyl amidecarbonyl-cyclobutane acetate with vinyl chloride, and of selected terpenes with ethylene and propylene. An evaluation sample of the copolymer of the afore-mentioned acetate with vinyl chloride (75% by weight) was prepared by using GRR soap (sodium laurate) as an emulsifier. Repeated precipitations from tetrahydrofuran gave white polymers, inherent viscosity 1.23, that on dissolving in the solvent gave colorless solutions. Conditions have been established for the production of terpolymers of ethylene-propylene-dipentene with varying amounts of unsaturation using Ziegler-type catalyst systems. Unsaturation in terms of grams of polymer containing one mole equivalent double bond ranged from 2720 to 67, inherent viscosities from 0.598 to 1.54, and softening range from 110-130 to 150-180° C. Samples of the terpolymers are being evaluated for vulcanizability. They may have industrial potential for this or other crosslinking reactions. Copolymers of vinyl chloride with vinyl 2,2-dimethyl-3-morpholineamidecyclobutane acetate, vinyl 2,2-dimethyl-3-di-n-butylamineamidecyclobutane acetate, and vinyl 2,2-dimethyl-3-piperidineamidecyclobutane acetate were prepared, purified, and their physical properties determined. (S4 1-89(C)).

Contract research at U. S. Industrial Chemicals Corporation has been initiated on the free-radical high-pressure copolymerization of ethylene with selected unsaturated gum naval stores compounds to produce industrially useful products. Conditions have been established for the free-radical high-pressure copolymerization of ethylene with β-pinene, dipentene, 3,7-dimethyl-1,6-octadiene, myrcene, alloocimene, and mixed resin acids. Maximum concentrations of these monomers for stable reaction were found to be 21, 12, 21, 14, 4, and 11%, respectively. Products containing 3% and 10% of the monomers were also prepared, where feasible, for evaluation. Reactions of monomers having less unsaturation were easier to control and produced more interesting looking products. Although the products were of too low molecular weight for blown film, some of them amy offer promise for less conventional plastics applications. (S4 1-115(C)).

Research on the application of the oxo and related reactions to terpenes and resin acids to produce alcohols, aldehydes, and acids has continued under contract at the University of Cincinnati. Optimum conditions have been worked out for hydroformylation of dipentene to produce a monounsaturated aldehyde in moderate yields (about 50%). It will be possible to use the aldehyde as such or to convert it to an alcohol, acid or amine by known methods. Attempts to produce difunctional derivatives by further hydroformylation of the aldehyde or by direct addition of formaldehyde to dipentene were unsuccessful. Abietic acid did not hydroformylate under normal conditions due to abnormal behavior with cobalt carbonyls. Further efforts will be made to obtain difunctional derivatives. (S5 2-45(C)).

Further contract research on the synthesis of terpene alcohols and glycols by reaction of selected terpenes (camphene, limonene, and α-pinene) with formaldehyde has been conducted at Cornell University. Good yields of 8-hydroxymethyl-camphene and its acetate have been obtained. Product yield and purity depend on the reaction conditions. With stannic chloride as the catalyst the major reaction product of camphene with formaldehyde is a hydroxymethyltricyclene; with boron trifluoride it is a meta-dioxane. The major condensation product of formadehyde with limonene has been identified as 10-hydroxymethyl-limonene. Yields and purity of this alcohol or its acetate have been improved but are still lower than with camphene. Alpha-pinene gives a complex mixture of products when either mild or strong acid catalysts are employed. The major alcohols prepared in this research will be evaluated from the standpoint of their conversion to esters and ethers, particularly polymeric or polymerizable ones. (S5 2-46 (C)).

The cooperative research with the Pulp Chemicals Association to develop a method for the determination of rosin and rosin derivatives in protective coatings has been completed. The method of analysis developed under this project should permit the use of small amounts of rosin in many formulations from which it was previously excluded. (S5 2-39(Rev.)).

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Chemical Composition and Physical Properties

Joye, N. Mason, Jr., Leoblich, Virginia M., and Lawrence, Ray V. 1965. The isolation of palustric acid from gum rosin. J. Org. Chem. 30, pp. 654-655.

New and Improved Industrial Products

Braun, J. C. and Fisher, G. S. 1965. Diels-alder reaction of α-terpinene with a-β-unsaturated nitriles. J. Org. Chem. 30, pp. 1478-1481.

Fisher, G. S. 1965. Advances in USDA utilization research on turpentine. Naval Stores Rev. 75(1), pp. 4-5, 11, 17-18.

Hedrick, G. W., Fisher, G. S., Lawrence, R. V., and Mazzeno, L. W., Jr. 1964. Pinonic acid. A new chemical for industry. U. S. Dept. Agr. ARS 72-34, 6 pp.

Hedrick, G. W., Lawrence, R. V., Summers, H. B., Jr., and Mazzeno, L. W., Jr. 1965. Levopimaric acid. A product for industry. U. S. Dept. Agr. ARS 72-35, 5 pp.

Joye, N. Mason, Jr., Roberts, Edward M., and Lawrence, Ray V. (SURDD); Gough, Laurence J. (Dept. Chemistry & Chemical Technology, England); Soffer, Milton D. and Korman, Oya (Dept. Chemistry, Smith College, Northampton, Mass.). 1965. The structure of the dicyclic diterpenoids of slash pine. The identity of elliotinoic acid and communic acid. J. Org. Chem. 30, pp. 429-431.

Malzahn, R. A., Griffith, J. H., and Marvel, C. S. (Univ. of Ariz.); Hedrick, Glen W., Lewis, J. B., Mobley, Carolyn R., and Magne, F. C. 1964. Polymers and copolymers of vinyl pinolate and some reactions with isocyanates. J. Polymer Sci.: Part A, 2, pp. 5047-5056.

Schuller, Walter H. and Lawrence, Ray V. 1965. The base-catalyzed isomerization of the resin acids. J. Org. Chem. 30, pp. 2080-2082.

Schuller, W. H., Lawrence, R. V., Mazzeno, L. W., Jr., and Soniat, M. B. 1965. Peroxides from pine gum. A new product for industry. U. S. Dept. Agr. ARS 72-36, 4 pp.

Schuller, Walter H. (SURDD), and Prebluda, Harry J. (Ed., Chemurgic Digest). 1965. Low cost peroxides from pine gum. Chemurgic Digest 23(2), pp. 3-4.

New and Improved Processing Technology

Wells, J. A., Halbrook, N. J., Lawrence, R. V., and O'Connor, R. T. 1965. Intensity of the C≡N stretching vibration in cyanethylene adducts of levopimaric acid. Appl. Spectry. 19, pp. 26-28.

Hedrick, G. W. August 4, 1964. Polymeric derivatives of 3-amino-2,2-dimethylcyclobutane-acetic acid. U. S. Pat. No. 3,143,529.

Summers, Hugh B., Jr. and Hedrick, Glen W. October 20, 1964. Paper size from pine oleoresin. U. S. Pat. No. 3,153,598.

II. MAPLE SAP AND SIRUP - PROCESSING AND PRODUCTS
Eastern Utilization Research and Development Division

Problem. The extensive unused stands of sugar maple trees are largely located in agriculturally depressed areas that are commonly devoted to small-scale dairy farming. Since only a small percent of the available sugar maple trees are presently tapped for sap production, and about 50% of the sirup consumed in the United States is imported, untapped sugar maples represent a good potential source of increased cash income for farmers in these areas. The maple area includes 14 states from Minnesota to Maine and south to Virginia. Under proper conditions, maple sirup can be a 6-weeks seasonal crop not in competition with other farm activities and with a per acre value equal to or exceeding that of other farm products. Based largely on recent research carried out in the Department and the State Experiment Stations, the methods of collecting and processing sap into sirup are being streamlined. This has resulted in greatly increased efficiency and larger hourly returns to the sirup producer for his labor. The advent of tube collection and transportation of sap has reduced the cost of sap handling 40% and has eliminated much hand labor. Oil-firing of evaporators and improved systems of steam removal have provided efficient and sanitary plants. The taphole germicidal pellets and sanitary methods of sap handling have tended to stabilize crop yields and standardize sirup quality. While the results of previous research have contributed to modernization of the industry, much more information is needed so that all operations for the production of high-quality maple sirup and other maple products can be conducted in a predictable, efficient manner. Not only can the low income farms be greatly benefited, but the existing maple industry can be put on a higher economic plane and modernized to be made competitive with other crop and livestock farming to bring about improved land use.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing program involving chemists, biochemists and microbiologists. These scientists are engaged in both basic and applied research in investigations concerned with the problems of improving sap handling and processing, producing high-quality maple sirup, and developing new outlets for all maple products while lowering the cost of the product. Most of this work is conducted at Wyndmoor, Pennsylvania.

The Federal scientific effort devoted to research in this area totals 3.2 p.m.y. Of this number 1.0 are devoted to study of the chemical composition and physical properties of maple sap and sirup, 1.0 to microbiology of maple products and 1.2 to new and improved food products and processing technology, including 0.2 p.m.y. in contract research on sap storage, with J. L. Sipple & Son, Bainbridge, New York. In the research work cooperation is maintained with personnel of the Federal Extension Service in maple-producing states and with Cornell University.

PROGRAM OF STATE AGRICULTURAL EXPERIMENT STATIONS

Research on maple sap, sirup and products involves four projects in three states including Pennsylvania, New York and Vermont. Investigations are currently concerned with central evaporator processing and its economic feasibility; study of sap flow and water movement in trees; modern sap collecting systems; and marketing systems and the potential demand for maple products.

The market potential and demand study has indicated that the U.S. is currently importing more maple products from Canada than U.S. production; that 50% of total U.S. production is sold retail by maple producers; and that 13% of the total is sold wholesale in consumer packages and 37% wholesale in drum containers. Additional research will examine the relationships of scale of production, advertising, sugarhouse location, time of sales, population density, production levels, and income levels.

The number of professional man years devoted to maple products utilization is 0.8.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

Investigations on maple sap and sirup to obtain information on which to base improved techniques for making better maple products at lower cost are being carried out in three different areas: (1) composition of maple flavor, (2) fermentation studies and (3) improvement in processing and products.

A. Composition Studies

1. Composition of maple flavor. The chemical nature of the maple flavor constituents that have been identified so far (vanillin, coumarin, syringaldehyde, coniferyl aldehyde, dihydroconiferyl alcohol, 2,6-dimethoxybenzoquinone, acetol, and cyclotene) suggests their possible formation from soluble lignins and from combinations with sugar break-down products. The data being obtained on the nature and source of maple flavor are of utmost importance in the development of improved processing methods and new maple products. Positive identification of sap-contained flavor precursors should be invaluable in selection of maple trees for propagation.

B. Fermentation Studies

1. Reclaiming buddy sap. Buddy sap produced when the tree comes out of dormancy yields an unmarketable sirup because of the unpalatable flavor. The use of the germicidal pellets tends to favor buddy sap production since it extends sap flow later into the spring. Removal of the buddy principle from sap by fermentation was successfully conducted on a commercial scale this year.

2. Ultraviolet sterilization of sap. The use of ultraviolet radiation for controlling microbial growth was investigated to furnish data essential for sap storage studies. This physical method of sterilization was highly effective even on rapidly flowing sap. No detectable effects on the flavor or color of the sirup made from the treated sap were noted. This process eliminates the objectionable features of chemical preservatives.

C. Processing and Products

1. New products. A new continuous process has been developed for the high-flavoring of maple sirup. This process permits utilization of the top grades of maple sirup (80% of U.S. production) for making blended (cane-maple) table sirup. Formerly, these blending sirups were a major import from Canada.

2. Central sap evaporation plants. Utilization of a cooperative-owned vegetable canning plant, normally idle during the maple sap season, as a central sap evaporation plant was successfully conducted on a pilot plant scale. These plants, because of the large capacity of their facilities, can (a) provide an outlet for sap produced in a large area and (b) lower sirup processing costs which should result in larger markets because of lower prices to the consumer.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Chemical Composition and Physical Properties

Filipic, V. J. and Underwood, J. C. 1964. Composition of maple sap and sirup. Some aromatic compounds in sap. J. Food Sci. 29, pp. 464-468.
Underwood, J. C. 1964. Collaborative study of the determination of formaldehyde in maple sirup. J. Assoc. Offic. Agr. Chemists, 47, pp. 548-550.
Underwood, J. C. and Filipic, V. J. 1964. Source of aromatic compounds in maple sirup flavor. J. Food Sci., 29, pp. 814-818.
Willits, C. O. 1965. Report on methods of analyses for maple products. J. Assoc. Offic. Agr. Chemists, 48, p. 144.
Willits, C. O. 1965. Report of liaison with committee E15 of the American Society for Testing and Materials. J. Assoc. Offic. Agr. Chemists, 48, p. 224.

Fermentation Studies

Kissinger, J. C., Sipple, L., and Willits, C. O. 1964. Maple sap delivered to a central evaporator plant -- a progress report. Natl. Maple Syrup Digest, 3, pp. 8-10.
Wasserman, A. E. 1964. Yellow pigment production by Pseudomonas geniculata in maple sap. Appl. Microbiol., 12 (3), pp. 287-288.
Wasserman, Aaron E., and Willits, C. O. 1964. Maple sirup. XXII. Controlled fermentation of buddy maple sirup. Food Technol. 18, pp. 1966-1968.

New and Improved Food Products and Processing Technology

Robbins, Putnam W. 1965. Influence of tapping techniques on maple sap yields. Mich. Agr. Expt. Sta. Res. Report No. 28, 3 pp.

Sipple, Lloyd, Winch, Fred, and Willits, C. O. 1964. Multiple evaporator installations. Natl. Maple Syrup Digest, 3, pp. 6-8.

Willits, C. O. and Sipple, Lloyd. 1964. Facilities for the manufacture of maple confections. Natl. Maple Syrup Digest, 3, pp. 10-12.

III. RANGE SEEDING, ESTABLISHMENT, AND MANAGEMENT AND VARIETY EVALUATION ON FOREST RANGES
Crops Research Division

Problem. Grazing lands of the United States occupy almost one billion acres as compared to 350 million acres of all harvested crops. Presently more than half of all the nutrients consumed by domestic livestock come from pastures and ranges. With increasing population and increased demand for livestock products, the proportion of nutrients from pastures and ranges is expected to increase. More precise information is needed for many situations, information about what plants or mixtures meet the requirements for yield, nutritional value, and resistance to heat, cold, drought, and pests. Some of the major categories needing research attention are concerned with seeding and establishment, and include basic and applied physiological and ecological studies on the response of pasture and range species, biochemical constituents, and morphological development of the plant under grazing.

USDA PROGRAM

The Department has a continuing long-term program involving agronomists, plant physiologists, range scientists, and chemists engaged in basic and applied research on the management and improvement of grazing lands.

There are two P.L. 480 projects in Israel; one concerns developmental physiology of perennial pasture grasses. The other investigates establishment and maintenance of seeded dryland range under semi-arid conditions.

The Federal scientific effort devoted to research in this area totals 2.7 professional man-years. Of this number 1.2 is devoted to seeding and establishment, 0.8 to physiology, and 0.7 to quality and variety evaluation.

PROGRAM OF STATE EXPERIMENT STATIONS

In recent years emphasis has been directed toward basic studies involving the understanding of principles, although surveys and other forms of applied research continue to be important. Vegetation re-establishment studies on the better range and pasture lands are an important part of the research program. Species evaluation, seeding techniques, and cultural practices are studied in an overall attempt to increase the productivity of these areas. Progress requires the combined efforts of agronomists, plant physiologists, climatologists, biochemists and range ecologists. Because

of the great diversity of problems encompassed in this research, scientists work together through the mechanism of regional research projects such as: W-15 (Economics of rangelands), W-25 (Improvement of rangelands), W-34 (Range livestock nutrition) and W-48 (Weather environment).

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Seeding and Establishment

1. Site is of major importance in grass seedling establishment. Near Las Cruces, N. Mex., seedling emergence of black and sideoats grama, and lehmann and boer lovegrass was excellent on a sandy loam site rootplowed for creosotebush control. On a silt loam site rootplowed for tarbush control, only a few seedlings of tobosa, alkali sacaton, and sacaton emerged. Seedlings averaged 2 inches tall at the close of the growing season under dead brush on the creosotebush area but were only 1/2 inch tall in open areas. In a basin pitted area from July 29 to September 22, there was an average of 20 days of available soil moisture at a 1/2-inch depth under a brush cover 6 inches from the bottom of the pit. At 36 inches, there was an average of 14 days of available moisture. Without cover, there were only 15 days of available soil moisture 6 inches from the bottom of the pit and 11 days of available moisture at 36 inches. Adjacent flat areas averaged only 8 days of available soil moisture at the 1/2-inch depth. Relatively light dead plant cover reduced soil temperatures up to 41 degrees at a 1/2-inch depth when compared to areas without plant cover.

2. Sand dropseed no longer considered a weed on Southern Plains rangelands. Studies at Woodward, Okla., have shown that sand dropseed and native tall grasses are complementary to one another. During drought periods yield of tall grasses declined to approximately 80 lbs/acre while sand dropseed increased to 650 lbs/acre. During wet years tall grasses increased to 850 lbs/acre while sand dropseed decreased to 50 pounds. As a result of this complementary action, range production on sandy soil at Woodward tends to stabilize at around 700 lbs/acre. Sand dropseed is the only important grass on the Southern Plains that increases during drought periods. It should be included in all seedings on sandy soils.

3. Crested wheatgrass equal to native grass in persistence. Crested wheatgrass has proved to be as well adapted to sagebrush sites in southern Idaho as native grasses. Studies of 20- to 32-year-old stands show that this grass has not died out under moderate grazing. It has withstood heat, cold, drought, disease, and heavy grazing well and has been more resistant to fire and severe grazing than native grasses. It has also spread more from volunteer seedlings than native species.

4. Podosporiella verticillata widely distributed in arid soils. The fungus, capable of destroying grass seedings, has been found to infect seeds planted in southwestern Canada, all of the 11 Western States and North Dakota. The fungus is quite prevalent in the sagebrush-grass vegetation zone, and is abundant in the shadscale and mountain brush zones. It has also been found in the Aspen-fir zone in northern Utah. Soils supporting Secale cereale, Bromus tectorum and other high seed producing annual grasses have high infection potential.

5. Seed treatment controls Podosporiella verticillata. The fungicides Captan 75, Arasan 75 and Semesan applied to the seed prior to planting resulted in increased germination and seedling emergence in laboratory tests or on native range where Podosporiella verticillata was present in the soil. For spring plantings, 8 ounces of Captan 75 or 6 ounces of Semesan or Arasam 75 per 100 pounds of seed gave good control. Fall plantings, where the seed might be dormant in the soil for several months, required 12 ounches of Captan 75 or 8 ounces of Arasan 75 to control the fungus. Semesan at 6 ounces was not adequate and heavier rates have not been tested. The following genera of grasses are susceptible to the fungus: Agropyron, Bromus, Elymus, Festuca, Sitanion, Secale, and Stipa. Infection has been low on Avena Fatua Phalaris arundinaceae and Oryzopsis hymenoides. In tests to date infection has not been found on Arrhenatherum elatius. Infection and damage are greatest in early fall seedings where limited moisture uptake results in slow germination.

6. Brush control improves fair-condition native range. A 40-acre pasture at Burns, Oreg., sprayed with 2,4-D for brush control in 1952 underwent significant species changes but doubled beef production per acre. When yield was adjusted to a median year, squirreltail and Junegrass increased rapidly for 2 years and then gradually declined to below the pre-treatment level. Idaho fescue and bluebunch wheatgrass increased slowly for 5 or 6 years, and have not begun a decline; cheatgrass, almost non-existent on the pasture prior to 1956, was, by 1960, the highest producing species, and has since equalled or exceeded bluebunch wheatgrass. Pre-treatment total herbage and beef production were 227 and 6.7 lbs/acre, respectively. These amounts have increased, as a result of the 1952 treatment, to 642 and 14.4 pounds, respectively; 89% of the variation in yield was accounted for by fluctuations in the crop-year precipitation.

7. Cactus removal does not affect blue grama production. Cactus was removed from 6 sites on the Central Plains Experimental Range near Fort Collins, Colo. in 1960. Blue grama was clipped from adjacent plots with and without cactus removal on each site from 1960 through 1964. Cactus removal did not result in increased production of blue grama. On light soils, 22% of the forage in untreated plots was within clumps of cactus and not available for grazing. On heavier soils 15% of the forage was not available.

8. Temperature affects germination of dryland grasses. Under a P.L. 480 project in Israel, it was found that all grass species tested germinated rapidly under 8-hour days at 4°C. and warm nights at 20°C. Germination was consistently inferior under reverse conditions. These differences were not accounted for by accumulated degree-hours.

B. Physiology

1. Nutrient cultures show deficiency symptoms and response to sulfur fertilization. Carefully controlled nutrient culture studies at Berkeley, Calif., demonstrated symptoms of sulfur deficiency in Italian ryegrass and Spanish clover. Yield responses to S fertilization were also shown. S deficiency in Italian ryegrass produced general chlorosis with young blades first showing a pale lemon-yellow color, yellowing of the entire upper-blade surface with a pinkish-red color along the blade edges, and under-surface of younger blades, a more than normal erect habit of growth, a reduction in length of internodes, and fewer fibrous roots but roots larger in diameter than those of non-deficient plants. Symptoms of S deficiency on Spanish clover were similar, but with severe S deficiency, brown spots were scattered at random over the upper and lower surfaces of the young leaflets. With an increase in S fertilization from .01562 to 1 mg. S per liter of solution on both Italian ryegrass and Spanish clover, dry weight of tops increased 4.9-fold and 4.5-fold, respectively; dry weight of roots increased 1.6-fold and 1.1-fold, respectively; and total dry weight of tops plus roots per unit of sulfur added decreased from 1,900 to 100 mg. and from 1,990 to 110 mg., respectively.

C. Quality and Variety Evaluation

1. Stocking rate and beef production influenced by soil. Studies at Woodward, Okla., over the past 20 years reveal gains per head under proper stocking to be relatively constant but gain per acre is strongly influenced by soil texture, particularly silt and clay content. These studies have shown proper stocking per section, and gains per acre to be as follows: Summerlong on Tivoli dune sand, 94 steers and 44 lbs. of beef/acre; Pratt loamy sand 116 steers and 57 pounds of beef; Pratt sandy loam 160 steers and 76 pounds of beef.

2. Proper grazing intensity important on Northern Plains rangelands. A 12-year study at Miles City, Mont. showed the cumulative effects of too many cattle per unit of land caused serious reduction in fertility of beef cows and growth rate of calves. Range forage production was reduced under heavy grazing. The more palatable and productive forage species decreased and the undesirable species increased. Carrying capacity was greatly reduced during drought. Undesirable soil characteristics influencing soil moisture storage occurred under heavy grazing and there was an increase in the cost of supplemental winter feeding and an increase in death losses.

3. Amount of forage removal determines profit. A 23-year grazing study near Nunn, Colo., has indicated the proper amount of annual forage removal during the warm season. The removal of approximately 40% of the perennial range forage each year has resulted in the maintenance of normal forage production, reasonable cattle gains, and higher monetary return per acre than either 20% or 60% removal. Heavy use of rangeland for 23 years did not alter species composition appreciably but it did lower production. After a few years of rest from heavy grazing, blue grama produced as much as that on lightly used range.

4. Technique for more accurate cattle weights. At Woodward, Okla., where it takes 3 to 4 hours to obtain initial cattle weights for grazing experiments, a technique was developed to obtain more accurate weights. Animals weighed first had no shrink, whereas those weighed later may have shrunk for as long as 4 hours. The problem was corrected by holding the first 20 steers in a separate pen and re-weighing them at 2-hour intervals to obtain an accurate constant to be used to correct shrunk weights.

5. Russian wildrye superior to native range for late fall grazing. Three year's results at Mandan, N. Dak., have shown that Russian wildrye pasture can extend the fall grazing season, an important need of Northern Plains livestock operators. Yearling steers were fall grazed on pastures of Russian wildrye and native grass that had been held all summer without grazing. The average grazing intensity was .62 and 1.38 head/acre, respectively. Steerdays grazing/acre were 84 on the Russian wildrye and 37 on native. Gains/head were 25 and .7 and gains/acre were 40 and 0, respectively. Production and consumption of dry matter were also much higher on Russian wildrye.

6. Sheep used to determine digestibility of meadow hay. Wether sheep in digestion crates at Burns, Oregon, were fed meadow hay harvested at weekly intervals from June 21 to August 9. Digestibility of measured constituents remained fairly constant through late June and early July and then decreased throughout July and early August. Digestibilities of nitrogen, dry matter, cellulose, and gross energy were 64, 65, 72, and 64%, respectively, for hay cut June 21, and 40, 51, 60, and 50%, respectively, for hay cut August 9. In another trial using meadow hay fertilized with various rates of nitrogen applied on 4 different dates there was no measured effect of the fertilizer on digestibility of nitrogen, cellulose, or dry matter.

7. Weeping lovegrass hay a good winter feed. Weaner steers made better winter gains from weeping lovegrass hay at Woodward, Okla., than from winter grazing of summer deferred weeping lovegrass range, or from winter on year-long grazed native range. Steers on weeping lovegrass hay and aftermath during winter gained 77 pounds/head and produced 89 pounds of beef/acre. On summer deferred weeping lovegrass range, winter gains were 12 pounds/head and 9 pounds/acre, while on native range gains were 69 pounds/head. When native range is summer deferred, steers usually produce 25 to 30 pounds beef/acre during the winter grazing season.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Seeding and Establishment

Ares, Fred N. 1964. Cry alarm. Killer loose. New Mexico Stockman, 29:4.
Bement, R. E., et al. 1965. Seeding of abandoned croplands in the Central Great Plains. Jour. of Range Mangt. 18:53-59.
Bleak, A. T., et al. 1965. Problems in seeding the arid shadscale (Atriplex confertifolia) vegetation zone of Utah and Nevada. Jour. of Range Mangt. 18:59-65.
Buffington, L. C., and Herbel, Carlton H. 1965. Vegetational changes on a semidesert grassland range from 1858-1963. Ecological Monograph 35:139-164.
Eckert, Richard E., Jr. 1965. The resource conservation area concept. Jour. of Range Mangt. 18:36.
Eckert, Richard E., Jr., and Dylla, A. S. 1965. Establishment of replacement vegetation following phreatophyte control. Range Mangt. Prog. Rpt. P. 38-40, Circ. R-13, Nevada Agr. Exp. Sta.
Eckert, Richard E., Jr., and Evans, Raymond A. 1965. Mountain meadow restoration. Range Mangt. Prog. Rpt. p. 37, Circ. R-13, Nevada Agr. Exp. Sta.
Eckert, Richard E., Jr., and Evans, Raymond A. 1965. Chemical control and understory response in the low sagebrush type (Artemisia arbuscula and A. longiloba). Range Mangt. Prog. Rpt. Circ. R-13, Nevada Agr. Exp. Sta.
Evans, Raymond A., and Eckert, Richard E., Jr. 1965. Non-tillage seeding with paraquat on cheatgrass-infested rangelands. Range Mangt. Prog. Rpt. p. 40-41, Circ. R-13, Nevada Agr. Exp. Sta.
Evans, Raymond A., and Eckert, Richard E., Jr. 1965. Chemical fallow for seeding perennial grasses on cheatgrass-infested rangelands. Range Mangt. Prog. Rpt. p. 37-38, Circ. R-13, Nevada Agr. Exp. Sta.
Hedrick, D. W., Hyder, D. N., and Sneva, F. A. 1964. Overstory-understory type grass seedings on sagebrush-bunchgrass range. Oregon Agr. Exp. Sta. Tech. Bul. 80, 31 pp.
Heinze, Donald H., Eckert, Richard E., Jr., and Tueller, Paul T. 1965. Ecological resource inventory of range watersheds in Nevada. Range Mangt. Prog. Rpt. p. 10-13, R-13, Nevada Agr. Exp. Sta.
Herbel, Carlton H. 1964. Brush control. The Cattleman Vol. LI 2.
Herbel, Carlton H. 1964. Jornada Experimental Range Research. The Cattleman Vol. LI 2.
Hull, A. C., Jr., and Holmgren, R. E. 1964. Seeding southern Idaho rangelands. U. S. Forest Service Res. Paper INT 10, 32 pp.
Hyder, D. N., and Bement, R. E. 1964. Sixweeks fescue as a deterrent to blue grama utilization. Jour. of Range Mangt. 17:261-264.
Hyder, D. N., Bement, R. E., and Remmenga, E. E. 1965. Frequency sampling of blue grama range. Jour. of Range Mangt. 18:90-94.
Pechanec, J. F., et al. 1964. Sagebrush control on rangelands. USDA Agr. Handbook 277, 40 pp.

Sneva, F. A., Rumburg, C. B., and Hyder, D. N. 1964. A summary of alfalfa investigations conducted on the Squaw Butte Experiment Station. Oregon Agr. Exp. Sta. Spec. Rept. 176, 19 pp.

Tueller, Paul T., Eckert, Richard E., Jr., and Heinze, Donald H. 1965. Plant communities in Nevada. Range Mangt. Progress Rept. for Nevada Agr. Exp. Sta. Circ. R-13.

Quality and Varietal Evaluation

Gifford, R. O., Ruf, R. H., Jr., and Eckert, R. E., Jr. 1964. Apparatus for extracting plant sap. Agron. Jour. 56:4.

Hylton, L. O., Jr., Ulrich A., and Cornelius, D. R. 1965. Comparison of nitrogen constituents as indicators of the nitrogen status of Italian ryegrass and relation of top to root growth. Crop Sci. 5:21-22.

Sullivan, J. T. 1964. Chemical composition of forages in relation to digestibility by ruminants. ARS 34-62.

Sullivan, J. T. 1964. Measurement of forage quality by chemical analysis 1963-1964 Proc. Amer. Grassland Council, 39-59.

IV. WEED AND BRUSH CONTROL ON FOREST AND RELATED RANGES
Crops Research Division

Problem. Losses to weeds and brush on grazing lands and present costs of their control total almost $1 billion. Brush infests 320 million acres of range and pasture land in the United States. In Texas alone, it is estimated that brush infests 88 million acres of the 107 million acres of grazing land. In addition, millions of acres are infested with weed grasses and other herbaceous weeds that displace valuable forage species, reduce production and quality of forage, cause poisoning of and physical injury to livestock and reduce the quality of animal products. Also, weeds frequently cause failures in establishment of new seedings. The losses caused by weeds and brush must be reduced by expanding research to find more effective chemical, biological, mechanical, cultural and combination methods of weed control. Expansion of fundamental studies on the physiological and biochemical responses of weeds and crops to herbicides can provide information on the relation between molecular structure of herbicides and their modes of entrance, movement, behavior, metabolism, persistence, and fate in plants and soils. Improved effectiveness of herbicides requires more information on the effects of environment, soil, plant structure, and method and time of application on plant responses. Research on the integration of herbicide and herbicide-cultural methods of weed control into management systems should be expanded.

USDA AND COOPERATIVE PROGRAM

The U. S. Department of Agriculture has a continuing long-term program in both basic studies and the application of known principles to the solution of weed problems. Although research is being conducted which has general application in all areas of weed control such as studies on herbicide evaluation, on the mode of action of herbicides, on fundamental principles of the role of surfactants in herbicidal effectiveness, and on the behavior and detoxification of herbicides in soils, only the research directly related to control of weeds and brush on grazing lands is included in this report. The latter includes studies of the life histories and growth patterns of individual weeds, principles of competition among weeds and forage plants and the use of cultural methods, biological agents and herbicides for their control. Comprehensive studies are made to develop principles, practices and methods of using herbicides and other weed control techniques in solving regional and national weed and brush problems in grazing lands.

Research on the control of brush and weeds on grazing lands is conducted cooperatively with State Agricultural Experiment Stations and with Federal agencies, including the Bureaus of Reclamation, of Land Management,

Department of the Interior, the Advanced Research Projects Agency and the United States Army Corps of Engineers, Department of Defense, and the Forest Service of the Department of Agriculture. Industrial companies cooperate in furnishing experimental chemicals, equipment, and funds essential to rapid progress in weed control investigations.

The Federal scientific effort devoted to weed and brush control research on rangelands in or near forested areas is 25.0 professional man-years and 2.0 professional man-years on the control of phreatophytes.

PROGRAM OF STATE EXPERIMENT STATIONS

State experiment stations are conducting basic and applied research in weed control. These studies involve evaluation of selective herbicidal properties of new chemicals, the nature, behavior, and effect of herbicides on their degradation products in and on plants and plant products; the mechanism of herbicidal action; influence of climate, plant morphology and soil characteristics on the effectiveness of herbicides in selectively controlling weeds and on their persistence in plant tissue.

Weed life cycles and growth habits are being studied under different environments to determine the most susceptible stage of vulnerability to herbicides and other control measures. Other aspects that are currently being investigated are: competition between weeds and desired plant successions following control measures including replacement vegetation and management practices. Relation between weeds and biological control organism that attack them in different environment is being studied on a limited scale.

Much of the research in weed control is being done via regional projects. The USDA cooperates on much of this research activity.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Weed Investigations - Grazing Lands

1. Poisonous and Other Herbaceous Weeds

a. Physiological and Ecological Studies.

Ecological Studies. In experiments at Lafayette, Indiana, the most important competitive factor in the establishment of forage legumes was found to be light when moisture supply is adequate. Light competition retards the vegetative regrowth potential by reducing the development of crown buds and shoots of birdsfoot trefoil. In the early stages of establishment, broadleaf weeds are more competitive than weed grasses.

Light competition from increased weed density is not as important as competition for moisture in the soil. Also roots from weed grasses such as yellow foxtail, giant foxtail, and crabgrass appear to contain substances which are inhibitory to the growth of corn roots. Of the three grasses mentioned, giant foxtail contains the greatest amount of inhibitor, if all three contain the same substance, or the most toxic if they are different.

Physiological Studies. A method for determination of phenoxy herbicides in forage plants has been improved in research at Ithaca, New York. Basically, the technique involves determination of the herbicide by electron affinity gas chromotography after extraction and improved liquid-liquid phase separations for cleanup. The method is good for 4-(2,4-dichlorophenoxy)butyric acid (2,4-DB), 2,4-D and silvex in alfalfa, red clover, bromegrass, timothy and orchardgrass. Birdsfoot trefoil presents minor difficulties because of a tendency to form emulsions.

Limited simulated rainfall appeared to enhance absorption of 2,4-DB in birdsfoot trefoil, alfalfa, bromegrass, orchardgrass and timothy. A definite period of time seemed to be necessary for the plant to metabolize absorbed herbicide regardless of a rainfall variable. Partial degradation of 2,4-DB, 2,4-D and silvex apparently takes place in ensilage of orchardgrass, bromegrass and timothy. On occasion, phenoxy herbicides in legume silage were not degraded. The reason for this is presently unknown. In the majority of cases, there was significant degradation of phenoxy compounds in legume silage.

The alkaloid content in the leaves of tall larkspur (Delphinium occidentale) and false hellebore (Veratrum californicum) was significantly increased following treatment with 2,4,5-T. Three species are known to be thus affected by this herbicide. Also at Logan, Utah, biochemical work on isolating and identifying the toxic substance from timberline milkvetch (Astragulus miser) proceeds slowly but some progress has been made.

b. Control Studies.

Weed Control in Pastures. A new herbicide, 1-(2-methylcyclohexyl)-3-phenylurea (siduron) was found to be effective for selective annual weed-grass control in new seedings of forage grasses. In Maryland and Missouri, siduron showed excellent promise for the control of annual weed grasses in plantings of Poa, Festuca, Agrostis, some Bromus species and many others. Roots of susceptible grasses do not penetrate nor develop in soils containing siduron. Rates ranging from 3 to 6 lb/A were adequate for the control of the weed grasses that germinated on or near the soil surface and rates up to 12 lb/A were tolerated without injury to the other grasses. In Indiana and Maryland, species with larger seeds such as

barnyardgrass, giant foxtail and other species capable of emerging from depths greater than 1 inch escaped injury when this herbicide was applied only on the soil surface. In Washington, siduron controlled 100% of the downy brome and medusahead at rates of 4 to 14 lb/A without injury to the crested wheatgrass planted in September just before preemergence herbicide treatments.

In Maryland, trifluralin applied at 2 lb/A before planting and incorporated to a depth of 5 inches, gave season long control of annual weed grasses. New seedings of alfalfa, birdsfoot trefoil, and crown vetch grew normally in comparison with the growth on untreated and mowed plots in the droughty 1964 season. It was necessary to apply 2,4-DB for control of quickweed, (Galinsoga parviflora), as trifluralin was relatively poor for dicotyledonous weed control. Also, trifluralin when incorporated in the soil in New York, controlled annual grasses and compared favorably with EPTC at 2 and 4 lb/A when managed similarly. Incorporating EPTC in narrow bands over the seeded row continued to look especially promising for birdsfoot trefoil establishment.

November applications of 1 lb/A 2,4-DB ester and dormant applications of 1/2 lb/A of bromacil eliminated yellow rocket without injury to alfalfa in Missouri.

Excellent weed control for the growing season resulted in plots of big bluestem, Indian grass and switchgrass, sand bluestem and sideoats grama from using atrazine and diuron at 4 lb/A and bromacil at 2 lb/A in Nebraska. There was slight injury to the perennial grasses treated with bromacil early in the growing season. But this was apparently outgrown during the later part of the season.

Stand counts in 1964 showed that repeated sprayings in 1963 with 4 lb/A of isocil and 5 and 10 lb/A of paraquat almost eliminated broomsedge in Mississippi. In other plots, broomsedge fertilized with nitrogen had almost 50% higher protein content in the young stages than those receiving no nitrogen. Six weeks later, most of the difference had disappeared and protein content was much less for all treatments. Nitrogen increased forage yields of broomsedge pastures.

Weed Control on Rangelands. A non-tillage method of seeding perennial grasses on downy brome-infested rangelands was evaluated for the third year in California and Nevada. In the 1964 experiment, good to excellent initial control of downy brome resulted from spraying paraquat at 0.5 lb/A. First year seedlings of crested and intermediate wheatgrasses drilled in paraquat treated strips were comparable to those on disked and furrowed plots, and about four times better than those on check plots. Results indicate success of this technique.

In Idaho, about 90% control of bracken fern resulted from 2 lb/A of picloram, 8 lb/A of dicamba and a mixture of dicamba and 2-(2,4-dichlorphenoxy)propionic acid (dichlorprop) at 6 + 2 lb/A. Also, in Washington, picloram at 2 lb/A gave almost complete kill, or inhibition of new rosette formation, of rush skeletonweed while the phenoxy herbicides 2,4-D, 2-methyl-4-chlorophenoxyacetic acid (MCPA) and dichlorprop at rates up to 4 lb/A gave only top kill and appeared to stimulate new rosette formation the fall following application. While Dalmatian toadflax was satisfactorily controlled at 3 lb/A of silvex or dichlorprop, equivalent control was obtained with 1/2 lb/A of picloram. Picloram at 1 1/2 lb/A was required for complete kill.

In Utah, spraying with the phenoxy herbicides just before the bud stage of growth effectively controlled false hellebore. It is probable that one retreatment will be necessary for eradication. Properly timed and repeated annual treatments for 2 or 3 years with 2,4,5-T or silvex was also required for adequate control of tall larkspur from high mountain ranges. Single applications of herbicides did not kill many of these poisonous weeds. The tremendous increase in the grasses and the large reduction of tall larkspur should be sufficient to reduce or prevent cattle losses from poisoning.

On the desert ranges of Utah, halogeton was completely controlled with 1/2 lb/A of paraquat. This herbicide is nonselective but might find use on small infestations or on areas where reseeding can be done immediately following treatment.

In Indiana, it was found that potassium azide was an extremely active herbicidal material whether applied pre- or postemergence. Early evidence suggests that it can kill dormant weed seed in the soil and that it has a short persistence. It also has killed perennial root stocks of Canada thistle.

In Missouri, 2 annual applications of the esters of 2,4-D and 2,4-DB were about equal for controlling ironweed. Surfactants added to 2,4-D and 2,4-DB did not enhance the effectiveness of the esters but they increased the effectiveness of an amine formulation of 2,4-DB. An application of 1/4 lb/A or more of picloram reduced ironweed stands about 80%. However, it was ineffective on coralberry and wild garlic.

2. Brush Control

a. Physiological and Ecological Studies

Studies in Texas have shown that the herbicidal effectiveness of paraquat and diquat are reduced when spray applications are made at cool temperatures (40-50°F). Laboratory experiments show that light and oxygen are

essential for a rapid bleaching of the plant pigment system by paraquat. Light, but not oxygen, is also essential for the changes in membrane permeability brought about by paraquat. Temperature influences changes in membrane permeability. Also, in laboratory studies, picloram inhibited the action of malic dehydrogenase from mesquite. The inhibition was greater than that of 2,4-D and was antagonistic with the oxidized and reduced forms of nicotinamide-adenine dinucleotide. Also a method to quantitatively measure movement of small amounts of 2,4,5-T in plants was developed.

Juniper. One-seed juniper grows in areas which receive half or more of the annual rainfall during May-October. Utah juniper grows in areas which receive half or less of the annual rainfall during these months. Alligator juniper does not seem to be affected by seasonal precipitation patterns in the Southwest. This information may aid in planning management practices, such as reseeding, following juniper control.

Mesquite. In Texas, it was found that the active translocation area in mesquite stems is a ring about 3 mm thick which includes the outermost xylem ring and the innermost 0.3 mm of phloem. Leaves of plants of one year old mesquite, winged elm and live oak under drought stress in a nursery translocated C^{14}-labeled urea, 2,4-D, dicamba and 2,4,5-T poorly when applied in August, but when applied in September to plants that had resumed growth following rain, they translocated these herbicides readily.

The relative importance of stomata, cuticle and trichomes as routes of foliar penetration, was studied by fluorescence microscopy in Arizona. The route of greatest entry is principally dependent upon the plant species. In those species where entry is gained by a combination of two or all three routes, it appears that the nature of the fluorochrome carrier or content of surfactant, may influence one route of entry to the partial or complete exclusion of effect on other routes. For example, some surfactants significantly enhance stomatal penetration, but seem to have relatively little effect on absorption of fluorochromes via trichomes.

Also in exploratory work in Arizona involving the in vitro inactivation of amitrole by mesquite the relationship between tissue age and the inactivation potential reported last year was corroborated. It has now been observed that the seed is moderately capable of inactivation, but by the age of 4 days, the cotyledons developed an extremely high inactivation potential. By the age of 14 days, this potential is largely lost even though the cotyledons are still green and apparently vigorous.

Absorption and translocation of an ester of 2,4,5-T in mesquite seedlings was significantly enhanced in Arizona by the addition of 40% or more dimethyl sulfoxide (DMSO) to the aqueous carrier. The enhanced activity of 2,4,5-T induced by the higher DMSO concentrations was observed at

light intensities ranging from 25 to 1,000 foot-candles. Synergism also existed between DMSO and dicamba or picloram, but to a considerably lesser degree. At a concentration of 20%, DMSO was antagonistic toward the action of all three herbicides. Specific physiological responses to these compounds were generally not related to the light intensity, with the exception that degree of root repression was positively correlated with light intensity. Anatomical and morphological responses to the 2,4,5-T-DMSO mixtures suggests that the latter compound increases uptake and general activity of 2,4,5-T, but that the two substances are probably not transported by the same mechanism or in the same tissues. Whereas, 2,4,5-T translocates principally to the meristematic regions such as the apical bud, the DMSO moves widely throughout the plant and concentrates in the leaf tips. For example, leaves immediately above the treated leaves show marked injury, whereas such leaves may completely escape visible injury when 2,4,5-T is used alone.

In Texas, a burley huller was modified into an effective mesquite seed thresher. The modified device is capable of threshing one bushel of mesquite pods in 1 1/2 hours. Approximately 150 hours were required to thresh this quantity of seed by hand. Seed of mesquite are required to produce plants for greenhouse and nursery research studies.

b. Control Studies.

In Nevada, control of green rabbitbrush ranged from 88 to 100% when sprayed with picloram at 1/2 and 1 lb/A, depending on the time of spraying. A June 22nd spraying date gave complete control at both rates while spraying on May 15 controlled green rabbitbrush 88 to 97%, respectively. At these rates of picloram, big sagebrush control was relatively ineffective. 2,4-D at 1 to 3 lb/A in these same experiments gave adequate control of big sagebrush, but control of rabbitbrush was less effective.

Picloram effectively controlled junipers and shrub live oak when applied either as a foliage spray or as soil treatments. Picloram, fenuron and polychlorobensoic acid (PBA) all killed most of the grass in the soil-treated area under individual alligator junipers. A marked increase in moss cover occurred under trees sprayed with picloram. Fenuron spot and strip treatments applied in 1961 and 1962 still showed effects on love grasses growing on sandy soil in 1964. Initial responses to large (1/4 inch diameter) pellets of fenuron were equal to or better than standard size pellets, and pellets containing 50% fenuron were equal to or better than 25% pellets applied to a shrub live oak at two different areas in 1964.

In Missouri, picloram applied in 1963 at 1 lb/100 gal. was not as effective as 4 lb/100 gal. for defoliating persimmon in 1964. Soil applications of 5 to 10 lb/A of picloram was about equal to 8 lb/A of

dicamba for defoliating persimmon. However, foliage applications of dicamba gave greater control of persimmon than did picloram. Conversely, picloram was more effective on sassafrass. In Maryland, picloram controlled multiflora rose growing in hedges whether applied as foliage sprays or soil treatments at the bases of the plant. Only one application, either as a 1 lb/100 gal. of picloram in water spray or 5 lb/A soil treatment was needed in May 1963 to kill existing plants as determined in October of 1964. Native forbs and grasses grew well vegetatively and matured normal seed in 1964.

Picloram at 1/2, 1 and 2 lb/A effectively controlled huisache (Acacia farnesiana). Picloram and bromacil also show promise for control of live oak. Also, paraquat and paraquat combined with other herbicides usually gave most rapid leaf kill of live oak, mesquite and huisache. It appeared that mixtures of paraquat and picloram retained the rapid action of paraquat and appeared to retain the persistency of picloram on eastern Texas woody plants. In this area, picloram was effective against many woody plant species including sumac, sassafras, chinquapin and various grapes. In central Texas, picloram was effective for controlling whitebrush when applied at 4 lb/A, which rate also left a good grass stand. Granular applications to the soil were about equally effective as sprays.

Also in Texas, over 97% of the amine salts of 2,4-D, 2,4,5-T and dicamba disappeared within 16 weeks after application to silver and little bluestems and Dallisgrass at College Station but only 90% of these compounds disappeared in 16 weeks after application to sideoats grama at Spur. Lower rainfall (2.49 inches) was felt to be the main factor accounting for the lower disappearance rate at Spur.

In Puerto Rico, picloram had the broadest spectrum of effectiveness (number of species affected), of the herbicides evaluated. Where defoliation of all species is desired other herbicides may be required in combination because of differential susceptibility. It was found that defoliation from soil-applied herbicides took place rather slowly but the long-term effects were satisfactory. Soil-applied herbicides were more effective at the site where rainfall was lowest. Results may be influenced either by the amount of rainfall or by completely different species composition on the different sites. There was greater species diversity found at the Maricao site where the rainfall was intermediate and soils more porous than at the relatively wetter Luquillo site or at the drier Guanica site. Better soil drainage at Maricao prohibits soil saturation for an extended period.

Paraquat and diquat will defoliate guava within a week in Puerto Rico, but recovery was complete at the end of 6 months. Conversely, picloram was most effective in killing guava but the action was somewhat slower than that of paraquat and diquat.

In both Oklahoma and Texas, picloram shows promise for control of winged elm which has been tolerant of 2,4,5-T sprays. In both Oklahoma and Missouri, picloram was ineffective for the control of Symphoricarpos species. When applied as pellets to the soil around each cactus plant, picloram was effective for its control in Oklahoma. Also in Oklahoma, it was found that only small oak brush (1-3 inches in diameter) was killed by two annual April burnings. Trees larger than 3 inches in diameter were not affected. There was considerable more sprout growth on areas burned than on the untreated. On the other hand, 2,4,5-T ester applied either as a foliar spray or by injector gave good control of both small and large post and blackjack oaks. Native grass release and growth was best on 2,4,5-T treated plots. There was a significantly higher moisture content in the soil throughout the growing season through the 4 feet of sampling depth on 2,4,5-T treated plots as compared to those burned. Soil moisture was about the same for burned as for untreated.

In Oklahoma, triiodobenzoic acid added at 1/16 and 1/8 lb/A with 2 lbs. of an ester of 2,4,5-T per acre as foliage sprays gave nearly twice as much control of post and blackjack oak as spraying with an ester of 2,4,5-T alone. Oak defoliation was also more with the addition of 1/80 and 1/40 lb/A of thiocyanate to an ester of 2,4,5-T.

3. Phreatophytes

a. Physiological, Ecological, and Anatomical, and Biochemical Studies.

Anatomical studies of saltcedar seedlings at Los Lunas, New Mexico, showed that transition "crown-bud" zone between stem and root tissue was 2 to 3 cm long. Leaf vascular bundles had considerable xylem but few phloem cells. The seasonal growth of foliage in length on mature saltcedar began in late March and ceased in late June. Cuticle thickness reached its maximum by mid-May, but subepidermal cuticularization of secondarily thickened stems continued into late July and eventually enveloped four or more layers of cells. Turgidity studies of saltcedar foliage samples taken from field-grown trees at weekly intervals showed increasing water stress as the growing season progressed. Vegetative photoperiodic responses of saltcedar plants grown from cuttings were shown to include stem length, cuticle thickness, and xylem vessel member diameters, all of which were significantly greater under 14-hour than under 11-, 17-, or 8-1-hour photoperiods during 8-week periods of exposure.

Studies of movement and storage of salts in saltcedar showed that sodium is present in the greatest quantity and builds up in foliage coincident with the low level of carbohydrates in roots. About 60 percent of the sodium in the foliage can be removed by rainfall.

b. Control Studies

Silvex at 4 lb/A continued to be the most effective foliage-applied herbicide tested in New Mexico field experiments but it gave inconsistent and mostly inadequate control. Dormant cane spray applications of silvex at 8 lb per hundred gallons of diesel oil gave excellent control of saltcedar but costs of treatment were high.

Of 17 chemicals evaluated in greenhouse tests only picloram showed more effect on saltcedar than silvex. However, in field experiments picloram was not more effective than silvex and a mixture of picloram and silvex, each at 2 lb/A, was more effective than 4 lb/A of picloram alone. A combination treatment of mowing in winter and again in June followed by spraying with silvex in October and again in June is the most promising control method tested thus far on saltcedar.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Research Applicable to all Commodities

Butler, J. L. and E. W. Hauser. 1965. A subsurface herbicide applicator for small plots. (Abstract.) Proc. SWC. Jan.

Wooten, O. B. and J. T. Holstun, Jr. 1965. Calibration tables for power sprayers. Miss. AES Bul. 703. March.

Barrentine, W. L., O. B. Wooten, and J. T. Holstun, Jr. 1965. A progress report on the evaluation of soil incorporators-dye techniques. Miss. AES Bul. 702. March.

Jansen, L. L. 1964. Surfactant enhancement of herbicide entry. WEEDS 12:251-252.

McWhorter, C. G. and E. E. Schweizer. 1964. Effectiveness of a post-emergence split-application of herbicides for weed control. Proc. SWC, pp. 171-183.

Phillips, W. M., L. E. Andersen, and R. W. Campbell. 1964. Chemical weed control in crops. Kansas AES Bul. 467. Feb.

Shaw, W. C. 1964. Weed science-revolution in agricultural technology. WEEDS 12:153-162. July.

Shaw, W.C. 1964. Requirements for herbicides of the future. Proc. AAAS meeting, Montreal, Canada. Dec.

Weed Investigations - Grazing Lands

1. Poisonous and Other Herbaceous Weeds

a. Physiological and Ecological Studies

Cronin, E. H. 1965. Ecological and physiological factors influencing chemical control of Halogeton glomeratus. USDA Tech. Bull. No. 1325. Feb.

Monson, W. G. and F. S. Davis. 1964. Dormancy in western ironweed and leafy spurge. WEEDS 12(3):238-239.
Hagin, R. D. and D. L. Linscott. 1965. Determination of 4-(2,4-DB) and 2,4-D in forage plants. Jo. Agr. & Food Chem. 13(2):123-125.
Schreiber, M. M. 1965. Effect of date of planting and stage of cutting on production of giant foxtail. WEEDS 13(1):60-62.
Schreiber, M. M. 1965. Development of giant foxtail under several temperatures and photoperiods. WEEDS 13(1):40-43.

b. Control Studies

Cronin, E. H. and M. C. Williams. 1964. Chemical control of timber milkvetch and effects on associated vegetation. WEEDS 12(3):177-179.
Evans, R. A. and R. E. Eckert, Jr. 1965. Paraquat-surfactant combinations for control of downy brome (Bromus tectorum L.). WEEDS 13(2):150-151.
Kay, B. L. and R. A. Evans. 1965. Effects of fertilization on a mixed stand of cheatgrass and intermediate wheatgrass. Jo. Rge. Mgmt. 18(1):7-11.
Kerr, H. D., W. C. Robocker and T. J. Muzik. 1965. Characteristics and control of camelthorn. WEEDS 13(2):156-163.
Linscott, D. L. and R. D. Hagin. 1965. Legume seeding establishment with herbicides. Proc. NEWCC, 191-198.
McCarty, M. K. 1964. Control of annual and perennial ragweed and prairie threeawn in a weedy bluegrass pasture. (Abstract) Res. Prog. Rpt. NCWCC, 86.
McCarty, M. K. 1964. Control of whorled milkweed. (Abstract) Res. Prog. Rpt. NCWCC, 85.
Peters, E. J. 1964. Herbaceous weeds in pastures and forages. (Abstract) Res. Prog. Rpt. NCWCC, 81.
Peters, E. J. and J. F. Stritzke. 1964. Control of yellow rocket in alfalfa. (Abstract) Res. Prog. Rpt. NCWCC, 84.
Peters, E. J. and J. F. Stritzke. 1964. Weed control with herbicides in seedling cool season grasses. (Abstract) Res. Prog. Rpt. NCWCC, 90.
Peters, E. J. 1964. Preemergence, preplanting and postemergence herbicides for alfalfa and birdsfoot trefoil. Agr. Jour. 56(4):415-419.
Robocker, W. C. and C. L. Canode. 1965. Effects of litter, incorporated organic matter, soil type and selective herbicides on seedlings of downy brome. WEEDS 13(1):8-10.
Robocker, W. C., H. D. Kerr and V. F. Bruns. 1964. Characteristics and control of Swainsonpea. WEEDS 12(3):189-191.

2. Brush Control

a. Physiological and Ecological Studies.

Wills, G. D., E. Basler, and Harry M. Elwell. 1965. Factors affecting translocation of 2,4,5-T C^{14} in winged elm (Ulmus alata). (Abstract) Proc. SWC, 604.

Davis, F. S. and R. H. Priest. 1965. Effect of picloram on components of intermediary metabolism. (Abstract) Proc. SWC, 608.

Meyer, R. E., R. H. Haas and H. L. Morton. 1965. Mesquite stem, its structure, seasonal growth characteristics, and area of active xylary dye movement. Proc. SWC, 632.

Merkle, M. G. and A. F. Isbell. 1965. The herbicidal properties of some substituted quinolines. Proc. SWC, 662-666.

Johnsen, T. N., Jr. 1964. Ecology and control of alligator juniper. WEEDS 12(2):40-42.

b. Control Studies

Armstrong, C. G., M. R. Gebhardt and E. H. McIlvain. 1964. Goliath - A long-boom sprayer. Jo. Rge. Mgmt. 17(6):340-342.

Bovey, R. W., F. S. Davis, M. G. Merkle, R. E. Meyer, H. L. Morton and L. F. Bouse. 1965. Defoliation and control of brush. Proc. SWC, 288-292.

Hursey, R. A., H. L. Morton and F. S. Davis. 1965. An adaptation of the Bitterlich method of variable-radius plot sampling to the evaluation of brush control. Proc. SWC, 641-648.

Bovey, R. W. 1964. Control of yucca by aerial application of herbicides. Jo. Rge. Mgmt. 17(4):194-196.

Elwell, H. M. 1964. Oakbrush control improves grazing lands. Agr. Jour. 56(4):411-415.

Peters, E. J. and J. F. Stritzke. 1964. Picloram, 2,3,6-TBA and dicamba for control of persimmon (Diospyros virginiana L.) and sassafras (Sassafras albidum Nutt Nus.). Res. Prog. Rpt. NCWCC, 28.

3. Phreatophytes

Hughes, E. E. 1964. Research on control of phreatophytes. Proc. 9th Ann. New Mexico Water Conf.